WHAT WILL A GEOLOGIC REPOSITORY BE LIKE?

High-level nuclear waste is potentially hazardous for thousands of years. Under current plans, the United States will dispose of this waste deep underground in a geologic repository that must isolate the waste so that present and future generations and the environment will be protected from harmful exposure to ionizing radiation. To ensure the necessary long-term protection, the repository will include a system of multiple barriers.

4.10 Introduction

What will a geologic repository look like?

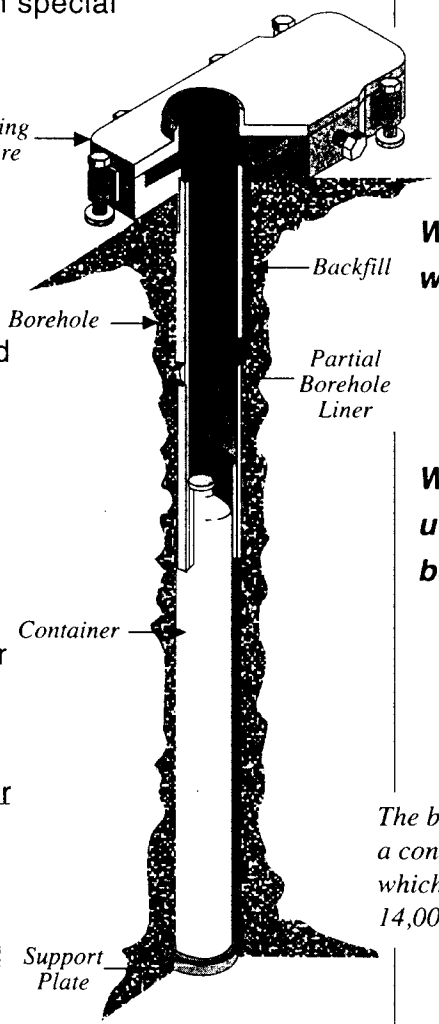
A geologic repository will resemble a large mining complex. The repository will combine two types of industrial facilities. A facility at the surface will be used for waste handling. A facility built about 305 meters (1,000 feet) below the surface will be used for permanent disposal of waste in special containers.

What type of facilities will be at the surface?

Surface facilities will include waste handling buildings, office buildings, fire and medical stations, water and sewage treatment plants, warehouses, repair and maintenance shops, and a security office. Shafts and ramps will connect the surface and underground areas.

What will the underground facility be like?

The underground facilities will include main tunnels leading to the areas where the waste will be placed. The disposal area will consist of smaller tunnels called *drifts* with *boreholes* in the wall or floor to accept the canisters of waste, or direct placement in the floor of the drifts. There will also be some service areas underground.



The borehole will accommodate a container about 16 feet high, which may hold as much as 14,000 pounds of spent fuel.

The earliest a repository is expected to begin operation is the year 2010. Waste disposed of at the repository will

Will future generations be alerted?

be retrievable for 50 years. During this time, the performance of the disposal system will be evaluated. After the repository is closed, steps will be taken to alert future generations about the location of the repository and why it should not be disturbed.

4.11 Performance Standards

What agencies developed requirements for repository performance?

The purpose of a repository is to protect present and future generations and the environment from the potential hazards of high-level waste. Scientists understand these hazards very well. Based on scientific understanding of the nature of high-level waste and radiation, the U.S. Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) developed specific requirements for the performance of a geologic repository. The purpose of performance standards is to prevent radiation exposures as the result of high-level waste disposal and to prevent contamination of certain sources of ground water near the disposal facilities.

What are some key requirements?

EPA standards, which the NRC is responsible for enforcing, require that the disposal system must be designed to provide a reasonable expectation that, during 10,000 years, cumulative (total accumulated) releases of radioactive isotopes to the environment will be kept within specific limits. Also, the waste packages must provide substantially complete containment of the waste for 300 to 1,000 years. Both the EPA and the NRC require the use of a system of multiple barriers.

Radioactive Decay Over Time

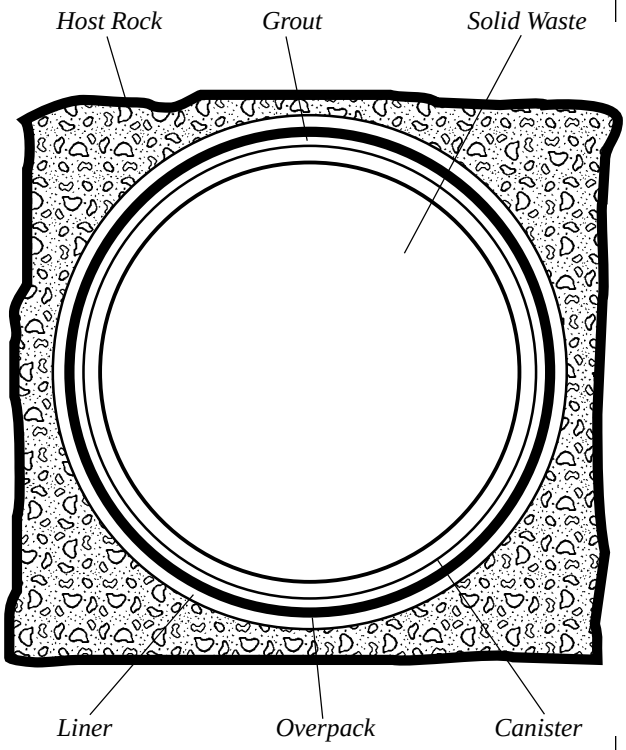
Why must the waste package provide "substantially complete" containment for the first 300 to 1,000 years of disposal? The fission product radioactivity in high-level waste decreases by more than 1,000 times in 300 years. It is almost gone in 1,000 years. The fission products react readily with other elements and, if they were allowed to, they would probably "migrate," or move away from the site of their disposal, toward the accessible environment. Therefore, during the period when their activity is high, they should be prevented from migrating. It is true that the "new" elements formed by the decay of the fission products may ultimately migrate, but they are not radioactive.

The other elements in high-level waste remain radioactive for tens of thousands of years. However, they are less chemically active and less likely to migrate.

4.12 Multiple Barriers

The *multiple barrier system* will include both engineered (manmade) and natural barriers. It will consist of 1) the waste package, 2) the repository itself, and 3) the "host rock" or geologic environment in which the repository is built. The use of a series of manmade and natural barriers is referred to as "defense in depth" because protection won't depend on one barrier only. Instead, the multiple barriers will work together to prevent or retard the release of radioactive material to the *accessible environment* — the environment outside the controlled area at a repository.

What are the three parts of the multiple barrier system?



The multiple barrier system will include both manmade (engineered) and natural barriers. A waste package placed in a borehole will look something like this, but details of the design are not yet decided.

What is the accessible environment?

4.13 The Waste Package as a Barrier

The waste package itself is the first barrier. The form of the waste is a key part of the waste package. Both spent fuel and defense waste will be disposed of as solids. No liquids will be disposed of in the repository. This decreases the potential for releases of radioactivity. The total package consists of the solid waste and everything that separates the waste from the host rock — containers, shielding, seals, packing, or any absorbent materials.

What will the physical form of the waste be?

Will liquids be disposed of in the repository?

Waste Form for Spent Fuel

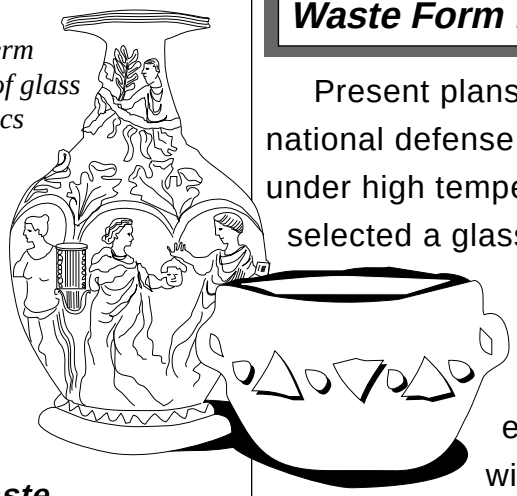
Spent fuel consists of ceramic pellets of uranium oxide that have been used in a reactor to produce electricity. The pellets are sealed in hundreds of metal tubes made from an alloy

How does the structure of a spent fuel assembly contribute to waste isolation?

Corrosion —Slow dissolving or eating away, especially by chemical action, such as rusting...*Corrosion slowly ruined the body of the car, which rusted away.*

(mixture of metals) that is mostly zirconium. This alloy resists *corrosion* and can withstand heat. Hundreds of the metal tubes, called fuel rods, are bundled together to form a fuel assembly. The spent fuel assembly is an important barrier because the waste remains "locked" in the pellets and tubes.

Waste Form for High-Level Defense Waste



The long-term durability of glass and ceramics is shown by ancient artifacts.

Present plans call for high-level nuclear waste generated in national defense activities to be solidified in a protective material under high temperatures. The U. S. Department of Energy selected a glass made of boron and silicon as the protective material designed to "immobilize" high-level nuclear waste. This material was selected for several reasons. 1) It is stable. 2) It is strong enough to be used in a repository. 3) It withstands *leaching* under conditions that could potentially exist in a repository. 4) It is suitable for large-scale, remote operations with highly radioactive waste.

What waste form will be used for disposal of defense high-level waste? Why is glass a good waste form?

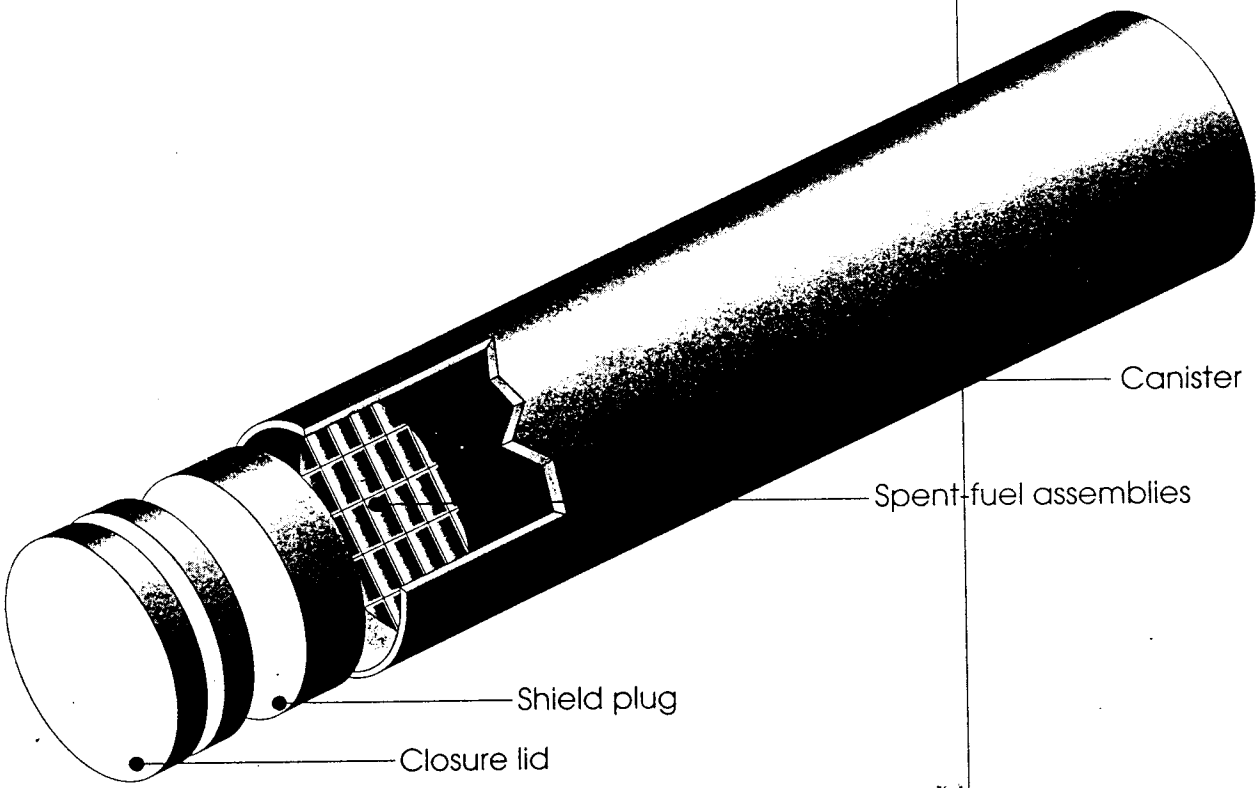
To solidify the waste, a mixture of high-level waste and molten glass will be poured into stainless steel canisters. After the glass cools to a solid, the canister will be plugged, welded shut, tested for leaks, decontaminated, and transferred to a temporary storage vault.

Leaching — Removal of parts that dissolve by the action of a liquid that seeps or drains through a porous substance... *As a result of leaching, the water leaving the garden carried pesticides into the nearby soil.*

Containers for Disposal

What will disposal containers be like?

Another engineered barrier is the disposal container. "Pour canisters" containing the solid glass form of defense waste will be sealed in special disposal containers. Spent fuel assemblies will also be placed in specially designed disposal containers (See lesson on Multi-Purpose Canisters). The disposal containers will be designed to prevent or delay exposing the wastes to any underground water that might be present. The containers will be made of materials that resist corrosion.



4.14 The Repository as a Barrier

What is the repository part of the multiple barrier system?

The repository portion of the multiple barrier system consists of engineered barriers that are not part of the waste package. Material used to *backfill* (or refill) underground storage rooms, passageways, ramps, and shafts is a major repository barrier used to limit or control movement of underground water.

What are boreholes and shafts?

How will they be sealed?

Borehole and Shaft Seals

A *borehole* is a hole drilled into the earth, often for exploratory purposes. Boreholes are usually small in diameter. A *shaft* is a vertical excavation made for mining rock, raising rock, lowering workers and materials, or ventilating underground areas.

Borehole seals and shaft seals are not included as part of the engineered system from a regulatory standpoint. However, borehole and shaft seals will be used to prevent or substantially reduce movement of water. These seals will also keep people from getting into the repository after operations have ceased. Tests are being conducted to identify materials that have the required engineering properties for seals. Materials being tested include clays, polymers, and cement grouts. (*Grout* is the type of material used as a filler for cracks or crevices with bricks or tiles. *Polymers* include rubber, resin, plastic, nylon, and other compounds with structures of long chemical chains.)

Besides acting as a barrier, backfill materials also serve other purposes in a repository. For example, backfill could enhance transfer of heat from the waste to the surrounding rock. It could be used to relieve or *mitigate* (make less severe) mechanical pressures or forces on the waste package. It could also provide structural support to the host rock surrounding the repository. Right now, the plan is to use some of the rock removed during mining for backfill. The backfill materials can be tailored to meet specific conditions by adding other materials, such as clays.

4.15 The Host Rock as a Barrier

How does the geologic setting serve as part of the multiple barrier system? What site features are important?

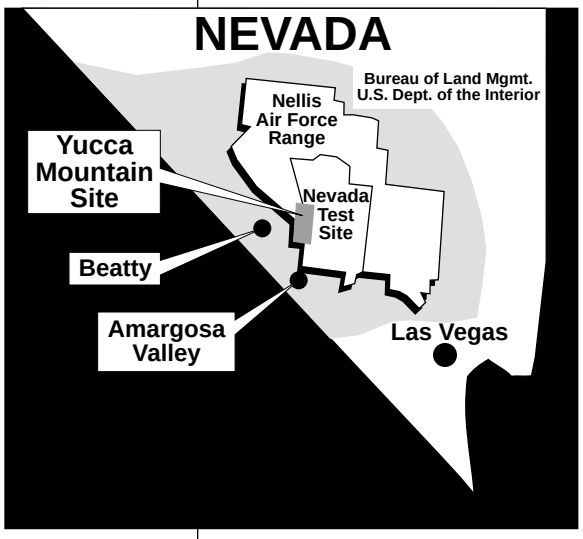
The site of the geologic repository plays a crucial role in isolating the buried waste from the accessible environment. It is the third major component of the multiple barrier system. Three features of a site that affect long-term isolation of waste are especially important: 1) the suitability of the host rock for construction of the repository and containment of waste; 2) the hydrology (water) and chemistry of the site and its environment and how they might interact with the waste; and 3) the time required for ground water to flow from the repository to the accessible environment. A geologic setting is very complex, and the factors that will serve as barriers depend on the characteristics of the specific site. The features of a site that affect long-term isolation of waste are being studied during site characterization.

Because a repository is more or less a special mine, some desirable site characteristics are related to mining and mine safety. Others include low ground water flow rates and long pathways from a repository to the accessible environment. It would be primarily through ground water flow that nuclear waste would migrate from the repository. Evidence of long-term geologic stability is desirable. The ability of the rock to conduct heat away from the waste package is particularly important. Radioactive waste is thermally hot and would heat the waste package, as well as the surrounding rock. Because heated rock tends to drive away water, this would help to reduce any migration of nuclear waste into the environment. Rock properties that prevent or slow movement of harmful substances are also desirable. Finally, as much as possible, the site selected should reduce the possibility of human intrusion.

What are some desirable site features?

4.16 If Yucca Mountain Is Suitable and Approved

The candidate site for a repository is Yucca Mountain, Nevada. This site is being studied to determine whether it is suitable. If this site is approved for development as a repository, the repository complex will use about 2,307 hectares (5,700 acres) that will include a controlled area 5 kilometers (3 miles) wide surrounding the outer perimeter. Utilities, roads, and a railroad line will be extended to the site.



If the site is chosen, the surface facilities will probably be on the east side of Yucca Mountain and will cover from 61 to 162 hectares (150 to 400 acres). Gently sloping ramps connecting the underground and surface facilities will allow shielded transport vehicles to carry waste packages to the underground disposal area. Underground facilities will be located about 1.5 kilometers (1 mile) west of the surface complex and will cover an underground area of about 567 hectares (1,400 acres). They will be about 305 meters (1,000 feet) beneath the surface.

If the Yucca Mountain site is approved, about how much land will be needed?

Unsaturated Zone

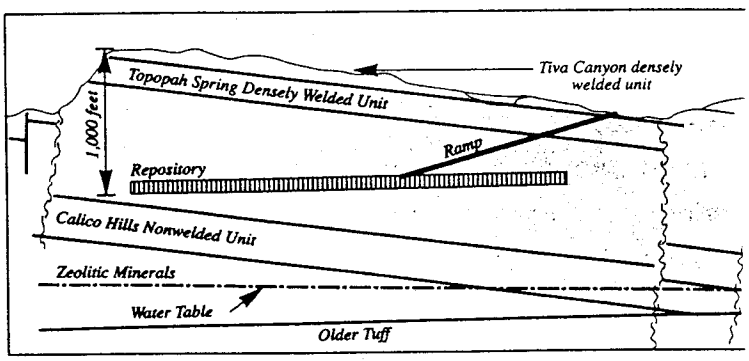
What are some distinctive features of the Yucca Mountain site?

The Yucca Mountain site has several distinctive features that may help to ensure that waste is isolated from the accessible environment if a repository is actually built there. Among these features are that the tuff rock deposits there are durable, and able to be mined. In addition, the proposed repository would lie in the *unsaturated zone*, 201 to 396 meters (660 to 1,300 feet) above the water table (the area of rock saturated with ground water). This feature would help to decrease water migration into the repository environment, and the flow of ground water at Yucca Mountain is being carefully studied to make sure that, if a repository is built there, the waste will remain isolated. However, other issues such as the potential for volcanic activity and earthquakes must also be considered.

Zeolites

Why is the presence of zeolites desirable?

Another distinctive feature of the Yucca Mountain site is that the repository would be located above a natural formation of minerals called *zeolites*. Zeolites are often used in water softeners. Because zeolites absorb minerals that make the water "hard," they could be helpful in removing certain radioactive ions, such as cesium-137 or strontium-90, if they should migrate from the waste package in a repository environment. Because the zeolites are positioned above the water table, radioactive elements coming from the repository could be filtered, preventing or delaying migration of waste into the water table. Through the friction of water moving through their tiny channels, zeolites would also slow down any contaminated ground water movement from the repository to the accessible environment.



The potential location of the repository in the unsaturated zone and the presence of zeolites are desirable features of the Yucca Mountain site that could contribute to long-term isolation of waste.